AFRL-HE-BR-TR-2005-0073

United States Air Force Research Laboratory

OPERATIONAL RISK MANAGEMENT OF FATIGUE EFFECTS

James C. Miller

HUMAN EFFECTIVENESS DIRECTORATE
BIOSCIENCES AND PROTECTION DIVISION
FATIGUE COUNTERMEASURES BRANCH
8248 CHENNAULT PATH
BROOKS CITY-BASE TX 78235-5105

May 2005

NOTICES

This report has been reviewed and is approved for publication.

//SIGNED//
JAMES C. MILLER, Ph.D.
Project Scientist

//SIGNED//
F. WESLEY BAUMGARDNER, Ph.D.
Deputy, Biosciences and Protection Division

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
May 2005	Interim	7-1-2004 to 9-30-2004

4. TITLE AND SUBTITLE OPERATIONAL RISK MANAGEMENT OF FATIGUE EFFECTS	**5a. CONTRACT NUMBER**
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) James C. Miller	**5d. PROJECT NUMBER** 7757
	5e. TASK NUMBER P9
	5f. WORK UNIT NUMBER 04
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Human Effectiveness Directorate Biosciences and Protection Division Fatigue Countermeasures Branch Brooks City-Base, TX 78235	**8. PERFORMING ORGANIZATION REPORT**
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Human Effectiveness Directorate Biosciences and Protection Division Fatigue Countermeasures Branch 8248 Chennault Path Brooks City-Base, TX 78235	**10. SPONSOR/MONITOR'S ACRONYM(S)** AFRL/HE **11. SPONSOR/MONITOR'S REPORT NUMBER(S)** AFRL-HE-BR-TR-2005-0073

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The document describes our first attempt to use a quantitative, applied model of fatigue and well-accepted fatigue countermeasures in the context of operational risk management. Identification of Fatigue Hazards: We listed the known, primary physiological and psychological effects of fatigue. These effects were aligned approximately with the cognitive and physiological tests shown to be sensitive to the fatigued state. The extrapolation of the listed effects to safety-sensitive jobs was explained through examples. Each effect had the potential to cause harm in military operations and, thus, was a hazard. Assessment of Fatigue Risks: Using the applied model of fatigue, SAFTE, we quantified the risks associated with five types of fatigue: physical fatigue, circadian effects, acute fatigue, cumulative fatigue, and chronic fatigue. Analysis of Fatigue Risk Control Measures: The best fatigue countermeasure is sleep, which is the only countermeasure that provides recovery. It also reduces the probability that fatigue will have an effect on mission safety and, concomitantly, reduces the exposure to fatigue. When adequate sleep cannot be used to counter fatigue, then one must consider the use of "Go" and "No-go" adjuncts, including schedule adjustments and pharmacological adjuncts. These adjuncts serve to reduce the severity of fatigue effects or the exposure to fatigue-related risk. Possible Fatigue Risk Control Decisions: All controls except sleep should be viewed as "band-aid" approaches, to be used as a last resort when other controls are insufficient and the mission must be accomplished. Recovery sleep will still be necessary after the other controls have been applied to accomplish the mission.

15. SUBJECT TERMS
Fatigue model, software usability, FAST, SAFTE, data input, controls and displays

16. SECURITY CLASSIFICATION OF: **UNCLASSIFIED**			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** Dr. James C. Miller
a. REPORT **UNCLASSIFIED**	**b. ABSTRACT** **UNCLASSIFIED**	**c. THIS PAGE** **UNCLASSIFIED**	**UNCLAS**	30	**19b. TELEPHONE NUMBER** *(include area code)* 210-536-2742

THIS PAGE INTENTIONALLY LEFT BLANK

CONTENTS

PREFACE

This report covers the project period of 1 July 2004 to 30 September 2004. The work was performed under Job Order Number 7757P904. The project manager was Dr. James C. Miller, Senior Research Physiologist, Fatigue Countermeasures Branch (AFRL/HEPF), Biosciences and Protection Division, Air Force Research Laboratory, Brooks City-Base, Texas.

SUMMARY

The document describes our first attempt to use a quantitative, applied model of fatigue and well-accepted fatigue countermeasures in the context of operational risk management. Identification of Fatigue Hazards: We listed the known, primary physiological and psychological effects of fatigue. These effects were aligned approximately with the cognitive and physiological tests shown to be sensitive to the fatigued state. The extrapolation of the listed effects to safety-sensitive jobs was explained through examples. Each effect had the potential to cause harm in military operations and, thus, was a hazard. Assessment of Fatigue Risks: Using the applied model of fatigue, SAFTE, we quantified the risks associated with five types of fatigue: physical fatigue, circadian effects, acute fatigue, cumulative fatigue, and chronic fatigue. Analysis of Fatigue Risk Control Measures: The best fatigue countermeasure is sleep, which is the only countermeasure that provides recovery. It also reduces the probability that fatigue will have an effect on mission safety and, concomitantly, reduces the exposure to fatigue. When adequate sleep cannot be used to counter fatigue, then one must consider the use of "Go" and "No-go" adjuncts, including schedule adjustments and pharmacological adjuncts. These adjuncts serve to reduce the severity of fatigue effects or the exposure to fatigue-related risk. Possible Fatigue Risk Control Decisions: All controls except sleep should be viewed as "band-aid" approaches, to be used as a last resort when other controls are insufficient and the mission must be accomplished. Recovery sleep will still be necessary after the other controls have been applied to accomplish the mission.

OPERATIONAL RISK MANAGEMENT OF FATIGUE EFFECTS

INTRODUCTION

This Technical Memorandum (TM) is provided for commanders, safety personnel, aerospace physiologists, schedulers, and others who help to assure the safe completion of Air Force missions that require sustained operations, night operations and irregular schedules. The TM describes our first attempt to use a quantitative, applied model of fatigue and well-accepted fatigue countermeasures in the context of operational risk management.

FATIGUE

Fatigue played a role in at least 143 USAF Class A mishaps from FY1972-FY2000 (Luna, 2003). Fatigue was cited as a major or causal factor in 26 USAF Class A mishaps over that same period and cost the Air Force an average of $54 million per year. From FY1990-FY2000, the most frequently cited component of fatigue was "circadian rhythm desynchrony" (cited 69 times), and "physical fatigue" was most often cited as having played the most significant role (21 times).

There are inherent, unavoidable, daily rhythms in human cognitive and physical performance (Appendix A). These rhythms cycle between their high point late in the day to their low point in the pre-dawn hours. Additionally, the state of wakefulness, itself, unavoidably induces the state of sleepiness. If sleep is not acquired, it induces involuntary, unplanned sleep (i.e., falling asleep on the job and at the wheel). As individuals work across the day and night, these rhythms and the states of wakefulness and sleepiness have direct effects upon cognitive and physical performance effectiveness.

Fatigue is a ubiquitous and pervasive problem. It is an enemy we always face when we deploy, when we fight and when we train. Fatigue in its many forms is often <u>mis</u>represented as an unavoidable risk in military operations, and its severity is often underestimated by those affected.

Each commander, supervisor and operator has a moral responsibility to protect our personnel from the possibility of fatigue-induced mishaps. The work we do with military systems can be hazardous enough, especially when we push the limits of the engineering envelope of a system. As long ago as 1796, Napoleon Bonaparte advised his subordinate commanders that they "must not needlessly fatigue the troops." Today, we have a quantitative, predictive, applied model that allows systematic considerations of fatigue-induced risks. These predictions may be applied to everyday operations through the process of operational risk management.

Fatigue is an abstract term that describes an internal state of a human operator. It takes many forms and in different degrees, both across people and within the same person at different times. For the purposes of this discussion, the types of fatigue were partitioned as follows[1].

[1] Definitions coordinated between AFRL/HEPF and AFSC/SEFL, Sep 2004, in response to an Inspector General recommendation (AFIA, 2004).

- PHYSICAL FATIGUE is a factor when the individual's diminished physical capability is due to overexertion (time or relative load) and it degrades task performance. [The effects of prolonged physical activity, or the effects of brief but relatively extreme physical activity, either of which taxes a person's physical endurance or strength beyond the individual's normal limits.]
- The CIRCADIAN RHYTHM is a factor when the individual's normal, 24-hour, rhythmic biological cycle degrades task performance. This is caused by one or more nights of work or rapid movement (faster than one time zone per day) across more than 3 time zones. These effects are referred to as "shift lag" and "jet lag," respectively. [Continuous time spent in the new time zone will lead to acclimation, but more acclimation time is needed for more time zones crossed. Acclimation to night work may never occur.]
- ACUTE MENTAL FATIGUE is a factor when the individual's diminished mental capability is due to prolonged wakefulness, usually more than 16 hours, that occurs between two major sleep periods and it degrades task performance [This acute, or transient, performance decrement should be eliminated after a regular sleep period.]
- CUMULATIVE MENTAL FATIGUE is a factor when the individual's diminished mental capability is due to disturbed or shortened major sleep periods between two or more successive major waking, duty or work periods and it degrades task performance. [One major sleep period will not eliminate cumulative fatigue.]
- CHRONIC MENTAL FATIGUE is a factor when the individual is exposed frequently during at least one month to multiple periods of prolonged wakefulness, excessive work hours, disturbed or shortened major sleep periods, unresolved conflicts, or prolonged frustration and it degrades task performance. An individual must display, concurrently, four or more of the following symptoms: the desire to sleep, apathy, substantial impairment in short-term memory or concentration; muscle pain; multi-joint pain without swelling or redness; headaches of a new type, pattern or severity; unrefreshing sleep; and post-exertional malaise lasting for more than 24 hours. The symptoms must have persisted or recurred for at least one month. [It is not eliminated by any number of sleep periods without first removing the cause.]

OPERATIONAL RISK MANAGEMENT

"Operational risk management [ORM] is a decision-making process to systematically evaluate possible courses of action, identify risks and benefits, and determine the best course of action for any given situation. ORM enables commanders, functional managers, supervisors, and individuals to maximize operational capabilities while limiting all dimensions of risk by applying a simple, systematic process appropriate for all personnel and functions both on- and off-duty. Appropriate use of ORM increases both an organization's and individual's ability to accomplish their mission, whether it is flying an airplane in combat, loading a truck with supplies, planning a joint service exercise, establishing a computer network, or driving home at the end of the day. Application of the ORM process ensures more consistent results, while ORM techniques and tools add rigor to the traditional approach to mission accomplishment, thereby directly strengthening the Air Force's warfighting posture." (AFI 90-901, *Operational Risk Management*, 1 Apr 2000)

The ORM process follows a 6-step sequence guided by four principles. The six steps are: identify the hazards, assess the risk, analyze risk control measures, make a control decision, implement risk controls, and supervise and review. These steps are addressed below.

IDENTIFICATION OF FATIGUE HAZARDS

In ORM, a *hazard* is a condition with the potential to cause illness, injury, death, property damage, or mission degradation. Hazard identification is a continual process and is an inherent responsibility of every individual involved in the operation. Using the research literature as a guide, we listed the known, primary physiological and psychological effects of fatigue in Table 1. Each effect has the potential to cause harm in military operations and, thus, is a hazard. Modifications to this list should be made whenever indicated by new research or operator experience. One day, the risk of each of these hazards may become quantifiable.

The specific effects listed here are aligned approximately with the kinds of cognitive and physiological tests used in research that have been shown to be sensitive to the fatigued state. The extrapolation of the listed effects to safety-sensitive jobs is explained through examples in the Glossary (Appendix C). Safety-sensitive jobs include such things as operating a vehicle (land, air, or water), making command and control decisions, operating a weapon, guarding public safety, etc.

TABLE 1. Fatigue-related effects (defined further in Appendix C).

FATIGUE-RELATED EFFECTS
1. Individual Differences
2. Basic Cognitive Functions
2a. Working memory impairment
2b. Anterograde amnesia
2c. Retrograde amnesia
2d. Cognitive impairment
2e. Slowed response time (RT) and reduced response accuracy
2f. Impaired manual control
2g. Vigilance impairment
2h. Narrowed attention
2i. Hypnagogic hallucinations
3. Complex Cognitive Functions
3a. Willingness to accept greater risk
3b. Loss of situation awareness
4. Mood & Motivation Impairment
5. Physiological
5a. General malaise
5b. Reduced aerobic capacity
5c. Drowsiness
5d. Sleep debt and need for recovery sleep
5e. Falling asleep on the job

5f. Dizziness
5g. Decreased altitude tolerance
5h. Decreased thermal tolerance
5i. Decreased acceleration tolerance
5j. Cardiovascular health effects
5k. Gastrointestinal health effects
6. Physiological Interactions
6a. Worsening of alcohol effects
6b. Modulation of drug effects
7. Interpersonal/Team Interactions
7a. Reduced interpersonal communications
7b. Impairment of shared situation awareness

ASSESSMENT OF FATIGUE RISKS

Once hazards have been identified, the risk of each hazard must be assessed and quantified. While each of the effects in Table 1 is a hazard under the ORM definition, above, it was virtually impossible to quantify the risk associated with each effect. Research had just not progressed far enough.

However, the fact that each of the effects in Table 1 has the potential to cause harm in military operations leads easily to the conclusion that needless fatigue, in general, is to be avoided in military operations. Thus, we chose to quantify the risks associated with the five types of fatigue defined above: physical fatigue, circadian effects, acute fatigue, cumulative fatigue, and chronic fatigue.

We had laid the groundwork for this approach in a previous effort. Investigators of workplace and transportation accidents and incidents seldom had the instruments or expertise required to determine whether or not human fatigue might have contributed to the mishap (AFIA, 2004). A Fatigue Checkcard and associated protocol were designed as a screening tool to fill this need (Miller, 2005). The Fatigue Checkcard was designed in part using the U.S. Department of Defense Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) applied model (Hursh et al., 2004), implemented as the Fatigue Avoidance Scheduling Tool (*FAST*™) software. The SAFTE applied model integrated the effects of length of prior wakefulness, amount of sleep and circadian rhythm.

Briefly, using the Checkcard, a mishap investigator could generate a fatigue-likelihood score based upon seven simple observations: length of prior wakefulness, amount of prior sleep for the preceding 72 hours, time of mishap, number of night shifts in preceding 30 days, time zone change and days in zone, types of human errors associated with mishap, and estimated physical exertion across the work period of interest. Because the Checkcard was an after-mishap rating instrument, and the ORM process is a pre-mission rating instrument, the sixth observation (type of human error associated with the mishap) was not applicable to the ORM process. The six remaining scores accounted well for the likelihood that one or more of the

five types of fatigue may have been present at the time of the mishap. Obviously, this kind of score is transferable to the ORM process.

In the ORM Hazard Probability-Severity matrix (Figure B-1), risks are specified as: 1-Critical, 2-Serious, 3-Moderate, 4-Minor, 5-Negligible, and 6-Unknown. Coincidentally, the Check card scores had been scaled 1 through 5, also, but with the opposite polarity. Thus, the transformation of Checkcard scores to ORM risk estimates appeared to be possible without re-scaling, requiring only reversed polarity. The rationale for the quantitative scaling of each of the seven fatigue hazards is discussed in the Checkcard Technical Memorandum (Miller, 2005) and, thus, is not repeated here. The 6-hazard, reversed-polarity risk assessment is shown in Table 2.

TABLE 2. Fatigue hazards and risk assessment scores (modified from the Fatigue Checkcard, Miller, 2005)

Fatigue Hazard	**Risk**
A. Length of Prior Wakefulness (LPW)	
LPW > 19 hrs	1
16 <= LPW < 19 hrs	3
LPW <= 16 hrs	5
B. Amount of Prior Sleep for the Preceding 72 h (APS)	
APS < 18 hrs	1
18 <= APS < 21 hrs	3
APS >= 21 hrs	5
C. Time of Day (TOD)	
0100 < TOD <= 0600h	1
2200 < TOD <= 0100h	3
0600 < TOD <= 2200h	5
D. Number of Night Shifts in Preceding 30 Days (NNS)	
NNS < 8	1
8 <= NNS <= 14	3
NNS >= 15	5
E. Time Zone Change and Days in Zone	
Time change of 6 to 12 hours and days in zone <= 1 day	1
Time change of 6 to 12 hours and days in zone > 1 day	3
[Any time change (hours) / Days in zone] < 3	5
F. Estimated Exertion Across the Work Period of Interest	
Extremely hard or maximal exertion	1
Very hard exertion	2
Somewhat hard or hard (heavy) exertion	3
Very light or light exertion	4
No exertion at all or extremely light exertion	5

The effects of these fatigue hazards are usually additive. In addition, if the level of risk associated with one hazard is quite high, then the potential cost is high, also. There were several possibilities for combining the risk estimates. These include averages (mean, median

and mode), a weighted mean, the maximum, and the sum. We recommend using a combination of the mean and the maximum: of the three averages, the mean will be affected more strongly by a high-risk outlier mixed with low-risk estimates than will the median or mode. This is may be a safer average score, in the risk-estimation context, than the median or mode. Thus, the scoring rules should be:

- If any hazard estimate is a 1 or a 2 (higher levels of risk), then the overall fatigue estimate equals the riskiest hazard estimate.
- Else, the overall fatigue estimate equals the equally-weighted mean of the six estimates.

Crews should use their judgment to provide interpolated scores of 2 and 4, as needed, for Hazards A through E and to adjust other risk estimates from these guidelines. However, the reasoning for interpolations and adjustments should be documented. Here are two simple scoring examples that differ only in the risk level for hazard C:

- Example using the mean: A-4, B-5, C-5, D-4, E-5, F-5
  - The overall fatigue risk level is (28 / 6 =) 4.7
- Example using the riskiest estimate: A-4, B-5, <u>C-1</u>, D-4, E-5, F-5
  - The overall fatigue risk level is 1

A discussion of each of the fatigue hazards follows. The discussion is oriented toward "crews." These may be aircrews or teams of people working on the ground or in the air.

<u>Hazard A, the length of prior wakefulness</u>, refers to the immediately preceding continuous period of wakefulness. Thus, if the period of interest is three hours after the crew has awakened from a night of sleep, the amount would be three hours and the risk score would be 1. If the period of interest is 20 hours after the last nocturnal sleep period, then the amount would be 20 hours and the score would be 5. The crew has some leeway determining the last "good quality" sleep period from which to start counting. Generally, nocturnal sleep is much better than daytime sleep for recovery from fatigue.

<u>Hazard B, amount of prior sleep for the preceding 72 hours</u>, refers to the total amount of "good quality" sleep acquired in that period. Again, the crew has some leeway in determining the occurrence of "good quality" sleep. Generally, nocturnal sleep is much better than daytime naps. <u>Hazard C, time of day/night</u>, should be self-explanatory.

For Hazard D, number of preceding night shifts in preceding 30 days, a lower risk number (higher risk) means that the crew has had fewer nights to acclimate to night work. If, on days off between night shifts, the crew reverted to a day waking and night sleeping pattern, then increase the score by 1 or more.

For the well-acclimated night crew who makes a change to day work, the same scores may be used as for the acclimation to night work. Change the description of the factor to "Number of preceding day shifts in 30 days" and document the immediately preceding acclimation to night work.

Similarly, for Hazard E, time zone change (in hours), a lower risk number means that the crew has had fewer days to acclimate to the new time zone. For example, consider a 6-hour time zone change. Up through 1 day (i.e., at least 24 hours) in the new time zone, the risk level would be 1. After 2 days in that new time zone, the risk level would be about 3. After 3 days in that new time zone, the quotient of hours and days would be (6 / 3 =) 2 and (2 being less than 3) the risk level would be 4. The calculations work for changes up to 12 hours (half-way around the globe). For changes greater than 12 hours, subtract the change from 24 hours and use the remainder in the calculation. For example, a 14-hour change becomes a (24 – 14 =) 10 hour change.

Hazard F, estimated exertion across the work period of interest, allows the crew to account for physical fatigue during the period of interest.

ANALYSIS OF FATIGUE RISK CONTROL MEASURES

Effective mitigation measures should reduce the probability of, severity of or exposure to risk (AFI 90-901). The main cause of fatigue is lack of adequate sleep (both quantity and quality). The best fatigue countermeasure is sleep, which is the only countermeasure that provides recovery. It also reduces the probability that fatigue will have an effect on mission safety and, concomitantly, reduces the exposure to fatigue. When adequate sleep cannot be used to counter fatigue, then one must consider the use of "Go" and "No-go" adjuncts. These adjuncts serve to reduce the severity of fatigue effects or the exposure to fatigue-related risk. The characteristics of each control measure are listed, below.

SLEEP

- Sleep debt should be avoided whenever possible. It is part of crews' duties to keep cognitive skills sharp through adequate sleep. Though one cannot "store" sleep, you can and should avoid the build-up of cumulative fatigue due to sleep debt. Policy-makers must be sharp every day and also be ready to pull an all-nighter, when necessary. Crews should always be rested and as ready as possible to accomplish night work. The minimum recommended amount of sleep is eight hours per night (yes, eight!).
- Recovery sleep is necessary and should be allowed for and planned for when a sleep debt exists. Fortunately, we are efficient at paying back this debt. You can pay it back two to four times faster than it accumulated. Thus, eight hours of debt can be paid back with two to four hours added onto eight hours of good-quality, nocturnal sleep (a total of 8 to 12 hours).
- Implement an in-office or in-squadron napping strategy to keep crews as sharp as possible.
    - Aircrews: "...controlled cockpit rest may be implemented when the basic aircrew includes a second qualified pilot." (AFI 11-202, *General Flight Rules*, Par 9.9.6)
- Emphasize good sleep hygiene and good nutrition. Refer to the National Sleep Foundation (www.sleepfoundation.org) for up-to-date information.
- Use no caffeine during the 6 hours before planned sleep, including planned naps.

- Consume no alcohol or only within legal limits (1 drink per hour) or less. While alcohol may shorten sleep latency, it reduces sleep length and quality.

"GO" ADJUNCTS

Reschedule or Truncate the Mission or the Duty Day

- The objective of this administrative control is to avoid the pre-dawn effects of the circadian rhythm and/or the effects of prolonged wakefulness.
- Aircrews: "PICs [pilots in command] must terminate a mission or mission leg if safety may be compromised by fatigue factors..." (AFI 11-202, *General Flight Rules*, Par 9.2.3)

Reduce Mission Work Demand

- The objective here is to match work demand to the level of crew fatigue.

Bright Light

- For crews who do not need to work in darkness or dim light, bright lighting overhead may suppress normal, nocturnal melatonin secretion and concomitant sleepiness. [In all-night command and control operations, computer displays that require dim ambient light for adequate viewing should be replaced with displays that are compatible with bright ambient lighting.]
- Bright light exposures in a new time zone before and after the expected sleep period may accelerate phase delays and phase advances, respectively, of one's circadian rhythms. However, in the absence of real-time, accurate knowledge of the expected sleep period, there is a substantial risk that inappropriately-timed bright light exposures will aggravate shift lag.
- <u>Given knowledge of this risk</u>, a crew may wish to refer to the calculator at the web site of Outside In, Ltd. (www.bodyclock.com). It appears that this calculator may be used safely, with three caveats.
  - First, emphasize to the crews that the times cited for light exposure are local at the new location.
  - Second, emphasize that going beyond the prescription (i.e., using it for more days than prescribed on the site) is not advisable. The reason for this is that, after a couple of days of light therapy in the new time zone, you no longer know exactly the timing of your expected sleep period.
  - Finally[2], emphasize to the crews that each person's response to the light exposure may vary. Thus, if it isn't working for you but it is for your friend, go with what your body is telling you, not what is happening with your friend. Your circadian rhythm may be slightly different from your friend's and therefore respond differently
- "Another way to look at the use of bright light to move the melatonin peak around is to imagine a long, skinny balloon that is inflated just in the middle and still skinny at both ends. The inflated bubble represents the melatonin peak that occurs between midnight and dawn. If you squeeze the right-hand part of the bubble, it will shift left. That's like morning light pushing the peak earlier. If you squeeze the left-hand part

---

[2] Dr. J. Lynn Caldwell, personal communication.

of the bubble, it will shift right. That's like evening light pushing the melatonin peak later."[3] What's not said clearly here is that the middle bubble is your <u>expected</u> sleep period, based upon your home sleep period and the sleep period's subsequent phase changes with respect to the new, local day-night cycle.

Caffeine

- Caffeine promotes wakefulness, enhances vigilance performance and lessens feelings of weariness.
- The half-life for caffeine metabolism is typically 5-6 hours.
- Be judicious with caffeine use. Use it sparingly so that you do not habituate to its excellent alerting effects: take it only every 3 to 4 hours and not in excessive amounts (limit to 250 mg/day or less).

Dextroamphetamine (Dexedrine®)

- Dextroamphetamine is one of the most potent central nervous system (CNS) stimulants. It has been demonstrated to increase concentration, as well as enhance physical performance in addition to modestly increasing the basal metabolic rate.
- The elimination half-life of dextroamphetamine is 12 hours. Peak blood concentrations occur at about 3 hours. Occasional side effects are rapid heart rate, elevated blood pressure, euphoria, dizziness, headache, diarrhea, and dry mouth.
- Dextroamphetamine is approved by the Air Force (AFI 48-123) for use as an alertness enhancer in both single-pilot fighter and dual-pilot bomber long-duration missions. The specific applications and requirements for the operational use of dextroamphetamine are presented in USAF/XO message 200958Z Feb 01 (Appendix M).
- Existing data indicate that 10mg doses of dextroamphetamine provide operationally relevant resistance to the effects of sleep deprivation in aviation contexts. Air Force guidance recommends 4-6 hours between successive doses of 10mg dextroamphetamine, and a limit of 60mg per 24-hour period.
- Retrospective studies on the use of dextroamphetamine in combat operations consistently report extended alertness in fatigued aircrews conducting long-duration missions, with no adverse side effects or a need to continue the drug after typical work/sleep schedules were reinstated (Cornum et al., 1995[4]; Emonson and Vanderbeek, 1993; Senechal, 1988).

Modafinil (Provigil®)

- Modafinil is a member of a new class of drugs called Eugregorics. Eugregorics mimic the alerting effects of amphetamines by producing high quality wakefulness in sleep deprived subjects, while lacking the negative side effects sometimes associated with amphetamines (modafinil is a schedule IV controlled substance; dextroamphetamine is a schedule II).

---

[3] Miller JC, *Controlling Pilot Error: Fatigue*, McGraw-Hill, 2001.

[4] The full citations for the research papers cited in the Control Measures section of the TM are available from the authors.

- Modafinil has a terminal half-life of 9-14 hours with peak blood concentrations 2-4 hours after absorption, making it a prime candidate for operational applications (Wong et al., 1997).
- Cephalon Inc. received FDA approval in 1998 to market modafinil for the management of excessive daytime sleepiness associated with narcolepsy, and very recently for treatment of shift-worker sleep deficit.
- Modafinil was approved for use in some AF operations by ACC/SG. Initially, the normal dose for AF operational use is 200mg orally every eight hours as needed, not to exceed 400mg in 24 consecutive hours. Preliminary reports from the field have suggested that for 24-hour and longer periods requiring continuous wakefulness, 600mg per 24 hours should be considered as an option.
- It has been consistently demonstrated in several studies that 100mg, 200mg and 300mg of modafinil administered either in single doses or, in split doses at four- or eight-hour intervals for longer periods of arousal, significantly enhances cognitive performance during extended periods of sleep deprivation (Bensimon et al., 1991; Lagarde and Batejat, 1995; Batéjat and Lagarde, 1999; Baranski et al., 1998; Stivalet et al., 1998).
- Unlike amphetamines, 100-300mg/day modafinil produces a long lasting waking effect without concern for behavioral modification, addictive attributes, adverse symptoms, or sleep rebound effects (Lagarde et al., 1995; Lin et al., 1997; Morehouse et al., 1997; Warot et al., 1993).
- Doses of 400-800mg/day have sometimes generated reports of headache, elevated pulse rate and blood pressure, dizziness, and sleep rebound (Caldwell et al., 2000; Batéjat and Lagade, 1999; Lagarde and Batejat, 1995; Buguet et al., 1995).

"NO-GO" ADJUNCTS

Declare Additional Crew Rest

- The objective of this administrative control measure is to allow needed sleep to be acquired.
- Aircrews: "The PIC [pilot in command] may recommend restricting duty time or extending crew rest periods to the MAJCOM approval authority. PICs must terminate a mission or mission leg if safety may be compromised by fatigue factors..." (AFI 11-202, *General Flight Rules*, Par 9.2.3)

Temazepam (Restoril®)

- Temazepam, a benzodiazepine compound, is approved by the FDA for short-term treatment of insomnia, providing symptomatic relief of difficulty in falling asleep, frequent nocturnal awakenings, and early morning awakenings.
- It has an elimination half-life of 8 hours and peak blood concentration at 1.5 hours. Although infrequent, the most common side effects are dizziness, drowsiness, nausea, and diarrhea.
- Temazepam is approved by the Air Force (AFI 48-123 and ACC/SG policy ltr 27 Sep 1999; Appendix M) for use by aircrew as a sleep aid during pre-mission crew rest. The Air Force directs that a dose not to exceed 30 mg temazepam be taken a minimum of 12 hours prior to reporting for duty to assure clearance and absence of hangover effects. The operational use of temazepam is restricted to a maximum of 7 consecutive days and no more than 20 days in a 60-day period.

Zolpidem (Ambien®)

- Zolpidem is a strong sedative with minor anxiolytic, myorelaxant, and anticonvulsant properties, and has been shown to be effective in inducing and maintaining sleep in adults with various sleep pathologies. Zolpidem is approved by the Food and Drug Administration (FDA) for short-term treatment of insomnia. Studies document that zolpidem produces no rebound or withdrawal effects and study subjects have experienced good daytime alertness after 20mg doses given at night.
- Peak plasma concentrations are reached 0.5 to 1.0 hours after ingestion. The elimination half-life averages about 2.5 hours. Although infrequent, the most common side effects of zolpidem are dizziness, drowsiness, nausea, and diarrhea.
- Zolpidem is approved by the Air Force (AFI 48-123 and ACC/SG policy ltr 27 Sep 1999; Appendix M) for use by aircrew as a sleep aid during pre-mission crew rest. The Air Force directs that 10mg zolpidem be taken at a minimum of six hours prior to reporting for duty to assure clearance and no hangover effects. Operational use of zolpidem is restricted to a maximum of 7 consecutive days and no more than 20 days in a 60-day period.

Zaleplon (Sonata®)

- Zaleplon is a short-duration sleep aid, similar in mode of action to zolpidem but shorter acting, with sleep onset occurring within 30-minutes of oral ingestion of a 10-mg tablet.
- The most common side effects include: headache, dizziness and somnolence. Outside of somnolence, in short-term clinical studies (Elie, Ruther, Farr, Emilien, & Salinas, 1999), the side effects for zaleplon are not significantly different from placebo. There is no evidence of rebound insomnia or withdrawal symptoms following discontinuation of the medication (10-mg dose).
- Zaleplon is approved by the Air Force (AFMOA/CC policy ltr 4 June 2001) for ground-based use by air crew and special duty personnel as a sleep aid. The use of zaleplon is restricted to a maximum of 10 consecutive days and no more than 28 days in a 60 day period.

Melatonin

- The naturally occurring hormone melatonin has received widespread public support as a safe and non-prescriptive means to induce sleepiness with typical doses of 3-10 mg. It has the distinct military advantage of not promoting sleep by CNS depression that would preclude personnel from going on duty before drug washout.
- The mean peak blood level for ingested melatonin occurs about an hour after ingestion and the elimination half life is about 2-3 hours across a wide variety of doses[i].
- Melatonin is primarily synthesized and secreted by the pineal gland but also produced in other tissues such as the retina.
- Melatonin is not currently approved for aircrew use in the United States Air Force[5].

[5] Air Force Surgeon General (22 Sep 2004). *Official Air Force Approved Aircrew Medications Quick Reference List.* AF/SGOP, Bolling AFB, DC.

POSSIBLE FATIGUE RISK CONTROL DECISIONS

"Decisions are made at the appropriate level and are based upon analyses of overall costs and benefits. Decision-makers choose the most mission supportive risk controls consistent with ORM principles." Primarily, decision-makers should "accept no unnecessary risk," but "accept risk when benefits outweigh the costs." (AFI 90-901). Napoleon espoused the first of these two principles.

To make a case for the second principle, one should probably avoid the conduct of safety-sensitive jobs when fatigue risk levels exceed three. This recommendation is made for two reasons. First, basic arithmetic: if the risk is "critical" (level 1), then it is difficult to imagine a situation in which benefit outweighs the potential cost.

Second, accuracy: the quantification of subjective estimates is not an exact science. One crew's risk level estimate of 2 may be a 1 for another crew and a 3 for still another crew. This lack of accuracy begs the allowance of a comfortable margin of error.

After controls have been selected to eliminate hazards or reduce their risk, one must determine the level of residual risk. "Residual risk is the risk remaining after controls have been identified, selected, and implemented for the threat. As controls for threats are identified and selected, the threats are reassessed, and the level of risk is revised. This process is repeated until the level of residual risk is acceptable to the commander or leader or cannot be further reduced." (AFTTP(I) 3-2.34, *Risk Management*, February 2001)

SLEEP

Good-quality, nocturnal sleep is a particularly effective control for the three hazards, Length of prior wakefulness, Amount of prior sleep, and Physical exertion. One method that can be used to calculate the amount of sleep needed for effective risk control is to estimate sleep debt and the amount of sleep needed to repay the debt. Sleep debt is the difference between an individual's desired, ideal sleep length and their actual sleep length, and it accrues from day to day. It is repaid at a rate of 1 to 2 hours of good-quality nocturnal sleep for every four hours of debt.

All controls except sleep should be viewed as "band-aid" approaches, to be used as a last resort when other controls are insufficient and the mission must be accomplished. Recovery sleep will still be necessary after the other controls have been applied to accomplish the mission.

RESCHEDULE OR TRUNCATE THE MISSION OR THE DUTY DAY

This approach is effective for the two hazards, Time of day and Time zone change and days in zone. The objectives are to (1) prevent safety-sensitive work from occurring at the nadir of a crew's body clock and (2) schedule the work when the crew's predicted cognitive performance effectiveness is at or above 90%.

REDUCE MISSION WORK DEMAND
This approach is effective for all fatigue hazards, especially if work demand can be reduced from safety-sensitive to non-safety-sensitive.

BRIGHT LIGHT
This approach may be effective for the hazards, Time of day, Number of night shifts, and Time zone change. It has been reported that bright light, used properly with respect to the expected sleep period (not a straightforward task), may accelerate acclimation to a new time zone by a factor of three. The non-bright-light rules of thumb for acclimation are 1 hour per day for westward travel and 40 minutes per day for eastward travel.

CAFFEINE, DEXTROAMPHETAMINE, AND MODAFINIL
These adjuncts are quite effective for all fatigue hazards. They may fully counter the effects of fatigue on cognitive performance effectiveness for limited periods.

DECLARE ADDITIONAL CREW REST
The objective here is to acquire more sleep. Thus, this control is effective for the three hazards, Length of prior wakefulness, Amount of prior sleep, and Physical exertion.

TEMAZEPAM, ZOLPIDEM, ZALEPLON AND MELATONIN
These adjuncts induce sleep. Thus, they are effective for the three hazards, Length of prior wakefulness, Amount of prior sleep, and Physical exertion. In addition, they may be used effectively to phase advance sleep before and during eastward travel across time zones. Their relative effectiveness levels for inducing and sustaining sleep are temazepam > zolpidem > zaleplon > melatonin. There are large individual differences in effectiveness across the three drugs (melatonin is a hormone). All three drugs should be tested by all personnel.

QUANTITATIVE PREDICTIONS
The human system is subject to biological changes and rhythms that introduce predictable variability. Quantitative models, implemented in software, can predict the timing and severity of fatigue episodes, given some well-substantiated assumptions about when and how much people will sleep on any given work-rest schedule. The Sleep, Activity, Fatigue and Task Effectiveness (SAFTE) model integrates quantitative information about (1) circadian rhythms in metabolic rate, (2) cognitive performance recovery rates associated with sleep, and cognitive performance decay rates associated with wakefulness, and (3) cognitive performance effects associated with sleep inertia to produce a 3-process applied model of human cognitive performance effectiveness. This model, implemented as the Windows® software, *FAST*™, may be used as an objective predictor of fatigue levels throughout a variety of sustained operations. The predictions can guide operators toward specific risk control options.

Having determined the level of residual risk, there are four possible paths to follow:

- Accept the plan as is: the benefits outweigh risks (costs), and residual risk is low enough to justify the proposed action. The decision maker must then allocate resources to control risk.

- Reject the plan out-of-hand: the risk is too high to justify the operation in any form.
- Modify the plan to develop measures to control risk: the plan is valid, but the current controls do not minimize risk adequately. Further work to control the risk is necessary before proceeding.
- Elevate the decision to higher authority: the risk is too great for the decision-maker's level of authority and all possible controls have been considered.

IMPLEMENTATION OF FATIGUE RISK CONTROLS

"Once the risk control decision is made, assets must be made available to implement specific controls. Part of implementing control measures is informing the personnel in the system of the risk management process results and subsequent decisions. Careful documentation of each step in the risk management process facilitates risk communication and the rational processes behind risk management decisions." (AFTTP(I) 3-2.34)

MAKE IMPLEMENTATION CLEAR

Presently, the *FAST*™ software allows decision-makers and schedulers to cut and paste graphs and tables into digital documents for word processing and slide shows. Additionally, it has a specialty function that prints a cockpit napping plan for extended (24 hours and longer) bomber missions.

Using our present, concept-demonstration software (*FAST*™) as a starting point, this Branch plans to demonstrate systematic, quantitative tools that empower commanders and schedulers to improve cognitive readiness and support risk-management actions. An iterative design process will be implemented in which we plan to:

- Visit sites to identify users' needs
- Incorporate needs into designs based upon the concept demonstration software
- Implement designs and document
- Conduct user assessments on-site
- Repeat steps, as needed

This process will produce a number of dedicated, prototype software tools. None may resemble *FAST*™, but all will draw upon the SAFTE code embedded in *FAST*™. We will document and certify each tool and it will be available to all DoD users who have needs similar to those users involved in tool design. This iterative design process is illustrated in Figure 1.

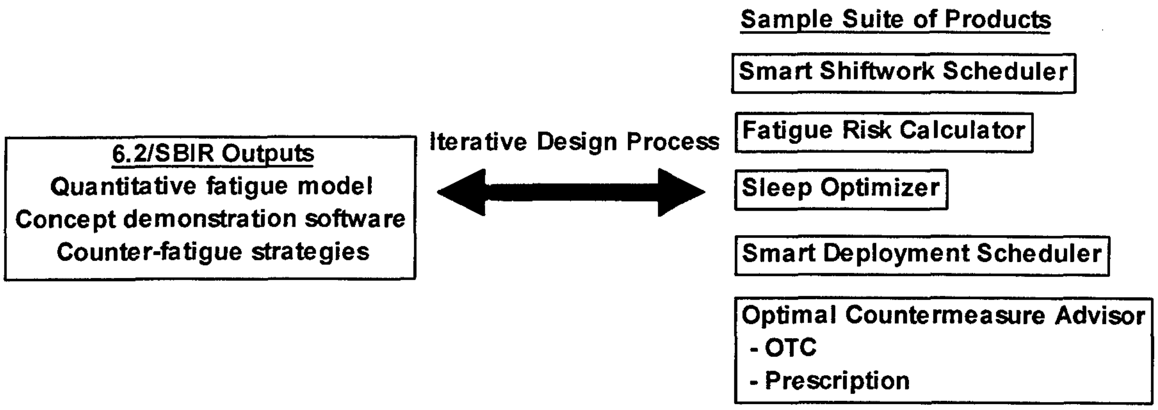

Figure 1. Iterative design process for fatigue risk management tools.

ESTABLISH ACCOUNTABILITY

Good sleep hygiene requires that management provide good sleeping quarters and that personnel use the quarters and practice good pre-sleep behaviors. More specifically, it means that management must provide a quiet, cool, dark, comfortable sleeping space and protect and maintain it; and that each individual must sleep during the rest period, avoid sleep disturbing practices and not ingest sleep disturbing compounds (e.g., alcohol, caffeine, nicotine) before sleep.

The use of prescription and non-prescription pharmacological adjuncts requires the medical support of the local SG. Also, the AF/SG has identified Flight Surgeons and Aerospace Physiologists as members of Human Performance Training Teams (HPTT). Where an HPTT is available, its members can help operators deal with fatigue risk management.

Good scheduling practices require education and training for schedulers with respect to interactions among times of day, sleep propensity, time zone changes and other factors. Toward this end, this Branch offers quarterly a course entitled Military Aviation Fatigue Countermeasures. The course is open to all personnel and deals with scheduling and fatigue countermeasures for both aircrew and non-aircrew personnel.

In addition, this Branch produces Technical Memoranda for the benefit of crew schedulers. The first three are dedicated to aircrews:

- *Scheduling Aircrews 1: Intra-Theater 24/7 Operations*
- *Scheduling Aircrews 2: Nighttime Missions*
- *Scheduling Aircrews 3: Deployment*

We have also been directed by the Air Staff to write an Air Force Manual on shiftwork scheduling (AFIA, 2004).

PROVIDE SUPPORT

The command must (AFTTP(I) 3-2.34):

- Provide the personnel and resources necessary to implement the control measures.
- Design for sustainability.

- Employ each control with a feedback mechanism that will provide information on whether the control is achieving the intended purpose.

SUPERVISION AND REVIEW

"There are three aspects: monitoring the effectiveness of risk controls; determining the need for further assessment of either all, or a portion of, the operation due to an unanticipated change; and capturing lessons learned, both positive and negative." (AFTTP(I) 3-2.34) The implementation of these functions is left to those using this Technical memorandum to help them practice fatigue ORM. **CAUTION:** Supervision and review should **not** be accomplished by fatigued supervisors. One of the characteristics of fatigue is the willingness to accept more risk than normal.

EXAMPLES

SHIFT WORK

Days

The risk associated with normal, regular daytime work is quite low. Imagine a permanent (non-rotating) 12-hour shift beginning at 0700h, with awakening from good-quality nocturnal sleep at 0600h.

- At the end of the shift, the length of prior wakefulness is 13 hours and the associated risk level is 5 ("negligible").
- The amount of prior sleep for the preceding 72 hours is likely to be 21 to 24 hours, with an associated risk level of 5.
- The time of day of the shift falls between 0600h and 2200h, with an associated risk level of 5.
- There have been no preceding night shifts, so that hazard is not a player.
- There have been no time zone changes, so that hazard is not a player.
- Let's say that the estimated level of exertion for the work shift is "hard", with an associated risk level of 3 ("moderate").

There are no risk levels of 1 or 2, so the mean is used to estimate the overall level of risk. The overall fatigue risk score for this example is (5 + 5 + 5 + 3 = 18; 18 / 4 =) 4.5 ("negligible" to "minor").

Nights

The risk associated with a week of night shifts is high. Imagine a crew on the 4th night of 12-hour shifts beginning at 1900h, with awakening from good-quality sleep at 1200h.

- At the end of the shift, the length of prior wakefulness is 18 hours and the associated risk level is 3.
- The amount of prior sleep for the preceding 72 hours is likely to be 15 to 18 hours, with an associated risk level of 1 ("critical").
- The night shift includes the period 0100h to 0600h, with an associated risk level of 1.
- There have been three preceding night shifts, with an associated risk level of 1.

- There have been no time zone changes, so that hazard is not a player.
- Let's say again that the estimated level of exertion for the work shift is "hard", with an associated risk level of 3 ("moderate").

There are risk levels of 1 or 2, so the worst risk level is used to estimate the overall level of risk. The overall fatigue risk score for this example is 1 ("critical").

FLYING

Days

The risk associated with normal, regular daytime flying is generally low, though time zone changes can have an influence on risk. Imagine the 3rd sequential 12-h crew duty period (CDP), about 0700h to 1900h local time (L), for a crew moving eastward, having crossed 6 time zones, with awakening from good-quality nocturnal sleep at about 0600h L.

- At the end of the CDP, the length of prior wakefulness is 13 hours and the associated risk level is 5 ("negligible").
- The amount of prior sleep for the preceding 72 hours is likely to be 18 to 21 hours, with an associated risk level of 3.
- The time of day of the shift falls between 0600h and 2200h L, with an associated risk level of 5.
- There have been no preceding night shifts, so that hazard is not a player.
- There have been 6 hours of time zone changes in the previous 2 days, with an associated risk level of 3.
- Let's say that the estimated level of exertion for the work shift is "light", with an associated risk level of 4.

There are no risk levels of 1 or 2, so the mean is used to estimate the overall level of risk. The overall fatigue risk score for this example is (5 + 3 + 5 + 3 + 4 = 20; 20 / 5 =) 4 ("minor").

Nights

Now imagine the 3rd sequential 12-h crew duty period (CDP), about 0000h to 1200h local time (L), for a crew moving eastward, having crossed 6 time zones, with awakening from good-quality nocturnal sleep at about 2300h L.

- At the end of the CDP, the length of prior wakefulness is 13 hours and the associated risk level is 5 ("negligible").
- The amount of prior sleep for the preceding 72 hours is likely to be 15 to 18 hours, with an associated risk level of 1.
- The CDP includes the period 0100h to 0600h, with an associated risk level of 1.
- There have been 2 preceding night CDPs, with an associated risk level of 1.
- There have been 6 hours of time zone changes in the previous 2 days, with an associated risk level of 3.
- Let's say that the estimated level of exertion for the work shift is "light", with an associated risk level of 4.

There are risk levels of 1 or 2, so the worst risk level is used to estimate the overall level of risk. The overall fatigue risk score for this example is 1 ("critical").

REFERENCES

Air Force Inspection Agency (2004). *Shift Worker Fatigue (FOUO).* Final Report of Eagle Look PN 04-602, Kirtland AFB, NM.

Hursh SR, Redmond DP, Johnson ML, Thorne DR, Belenky G, Balkin TJ, Storm WF, Miller JC, Eddy DR (2004). Fatigue models for applied research in warfighting. *Aviation, Space and Environmental Medicine*, 75(3), Section II, Supplement, pp. A44-A53.

Luna T (2003). Fatigue in context: USAF mishap experience (abstr). *Aviat Space Environ Med*, 74(4), p. 388.

Miller JC (2005). *A Fatigue Checkcard for Mishap Investigations.* Technical Memorandum AFRL-HE-BR-TM-200x-00xx, Air Force Research Laboratory, Brooks City-Base TX (submitted Sep 2004).

APPENDIX A
Fatigue Basics

In any human-machine system, the most variable (unpredictable) component in the system is the human. After training and currency, the greatest contributor to that variability is fatigue.

Good human-machine system design exploits human strengths and protects the system from human weaknesses. This is a fundamental concept in human factors engineering. The human brings to a system much more powerful pattern recognition capabilities and decision-making skills than can be provided in software. However, the human also brings much more performance variability to a system than one finds in software and modern hardware.

Training and currency are sources of human variability. When novices are learning to operate a complex system, they display a learning curve. Initially, their performance is quite poor and variable, but they learn the basics quickly. Next, their performance is better, on average, but still more variable than desired. Finally, as they approach the expert user level, their average performance is quite good and it varies only a small amount between excellent and good. Similarly, when an expert user becomes "rusty" in the operation of a complex system, their performance may be more variable than desired until after a few iterations.

One of the primary hallmarks of human fatigue is performance variability. This is due to large amplitude, moment-to-moment fluctuations in attentiveness associated with fatigue. Average performance may be acceptable, but there are brief periods when responses are extraordinarily delayed or absent ("lapses"). We often call this "distractibility."

We sort the generators of fatigue into the four categories circadian[6], acute, cumulative, and chronic. There are inherent, unavoidable, 24-hour rhythms in human cognitive and physical performance. Most of these <u>circadian rhythms</u> oscillate between their high point late in the day to their low point in the pre-dawn hours. <u>Acute fatigue</u> builds up unavoidably within in one waking and duty period, but recovery from acute fatigue is occurs as the result of one good-quality, nocturnal sleep period. <u>Cumulative fatigue</u> builds up across major waking and duty periods because there is inadequate recovery (due to inadequate sleep) between the duty periods, and recovery from cumulative fatigue is cannot be accomplished in one good-quality, nocturnal sleep period.

<u>Chronic fatigue</u> may set in after one to two weeks of cumulative fatigue. Its symptoms[7] are similar to those of Chronic Fatigue Syndrome (CFS). However, unlike CFS, the cause is known (continuing cumulative fatigue) and it occurs much sooner the 6-month diagnostic requirement for CFS. Chronic fatigue was once called "motivational exhaustion." While this label accounts for only one of several possible symptoms (apathy), it describes well the attitude that one observes in a person with chronic fatigue.

---

[6] From the Latin *circa*, about, and *dia*, day: A cycle length of about one day.

[7] The desire to sleep, apathy, substantial impairment in short-term memory or concentration; muscle pain; multi-joint pain without swelling or redness; headaches of a new type, pattern or severity; unrefreshing sleep; and post-exertional malaise lasting more than 24 hours.

Fatigue is ubiquitous, pervasive and insidious. By ubiquitous we mean that fatigue affects everybody. There are individual differences: a few people are truly more resistant to fatigue effects than others. Many people think mistakenly that they are more resistant to fatigue effects than others.

By pervasive, we mean that fatigue affects everything we do, physically and cognitively. Again, there are individual differences. In the physical domain, there are those who are inherently able to train to much greater levels of strength and endurance than the rest of us.

By insidious, we mean that often when we are fatigued, we are quite unaware of how badly we are performing. Most people have experienced the cognitive lapse associated with mild fatigue when they miss a freeway exit or realize suddenly that they don't remember the last mile or two driven on the highway.

Fortunately, the biological changes and rhythms that cause fatigue-induced variability in human performance are relatively lawful and predictable. We have quantitative models, implemented in software, that allow us to estimate and predict the timing and severity of fatigue episodes, given some information about when and how much people sleep. The quantitative approach is applied here to provide insight into the effects of night work on worker cognition[8].

There is no escape from fatigue. For day workers, acute fatigue begins to build at their awakening in the morning, whether or not they go to work. By late evening, they recognize the need to go to bed and get some sleep. In fact, their cognitive performance at this point is somewhat similar to the performance a person with a 0.05% blood alcohol content. For night workers, it is uncommon to fully acclimate to sleeping during the day. Thus, they sleep poorly and cumulative fatigue builds up from work shift to work shift. Most often, night workers are more fatigued at work than day workers.

[8] In this case, the ability to perform such functions as logical reasoning and mental arithmetic.

Appendix B
ORM Assessment Guidelines

Definition of Terms

- Risk Assessment – the process of detecting hazards and assessing associated risks
- Hazard - Condition with the potential to cause personal injury, death, property damage or mission degradation
- Risk – Expression of possible loss in terms of severity & probability
- Severity – the worst credible consequence which can occur as a result of a hazard
- Probability – Likelihood that a hazard will result in mishap or loss
- Control – A method for reducing risk for an identified hazard by lowering the probability of occurrence, decreasing potential severity, or both.

Six Steps of Risk Assessment

1. Identify the hazards
2. Assess the risk
3. Analyze risk control measures
4. Make a control decision
5. Implement risk controls
6. Supervise and review

ORM Principles

- Accept no unnecessary risk
- Make risk decisions at the appropriate level
- Accept risk when benefits outweigh the cost
- Anticipate and manage risk by planning.

Rating the Hazard <u>Probability</u>

The probability that a hazard will result occur:

- A – Likely to occur immediately or within a short period of time; expected to occur frequently
- B – Probably will occur in time
- C – May occur in time
- D – Unlikely to occur

Rating the Hazard <u>Severity</u>

The worst credible consequence which can occur as a result of the hazard:

- I – Can cause death, facility loss, or grave damage to national interests
- II – Can cause severe injury, illness, property damage
- III – May cause minor injury, illness, property damage, damage to service interests, mission degradation
- IV – Presents a minimal threat to personal safety or health, property, national, service, or command interests, or efficient use of resources.

Probability > Severity	A	B	C	D
I	1	1	2	3
II	1	2	3	4
III	2	3	4	5
IV	3	4	5	5

Figure B-1. The Hazard Probability-Severity matrix allows risk assessment as follows: 1, Critical; 2, Serious; 3, Moderate; 4, Minor; 5, Negligible; 6, Unknown.

APPENDIX C
Glossary

1. ***Individual differences.*** Some of the problems caused by individual differences include (a) the inability to predict, within a group of personnel experiencing the same night work or extended or irregular schedule just who will be most susceptible to fatigue and who will not; and (b) scheduling around peoples' different physiological sleep needs (generally, 6 to 9 hours) and schedules (owls and larks). For example, during surge or night operations, a supervisor may expect that someone in his/her team may fall asleep on the job. However, the supervisor cannot predict who or exactly when, and thus is at a disadvantage for managing this risk. Additionally, (c) medical ground testing of any pharmaceutical countermeasure to fatigue should characterize each individual's reaction, and serve to prevent the occurrence of dangerous reactions during the performance of safety-sensitive jobs.

2a. ***Working memory.*** The focal point for human information processing. The scratch pad upon which you make mental comparisons and integrate new information with old information. Important for command and control teams and for aircrews, and affected strongly by moderate fatigue. For example, working memory impairment may cause an inability to remember radio frequencies or other information during the few minutes after receiving the information.

2b. ***Anterograde amnesia.*** The inability to remember needed, new information after it is presented. Especially critical for command and control teams and for the pilot's crosscheck. For example, an inability to recall flight parameters briefed before take-off.

2c. ***Retrograde amnesia.*** The inability to remember needed, old information. This is why we use hard-copy and computerized reference sources.

2d. ***Cognitive impairment.*** Includes decrements in response time and/or accuracy in tasks such as logical reasoning and relatively simple mental arithmetic. Also includes impaired decision making. Especially important for command and control teams and for aircrews. *Cognitive functions, basic.* The functions required to perform more complex, integrative cognitive tasks; infrastructure. *Cognitive functions, complex.* Complex, integrative functions.

2e. ***Slowed response time (RT) and reduced response accuracy.*** Includes decrements in response time and accuracy in tasks such as simple reaction time tasks through choice reaction time tasks to logical reasoning and mental arithmetic. Especially important for aircrews and affected strongly by moderate fatigue. For example, hesitation in identifying a problem or a target and/or not taking definitive or appropriate action.

2f. ***Manual control.*** For example, steering a car or flying with stick and rudder. When these tasks are learned to the point of automatic behavior, as they are in licensed drivers (most of them, anyway) and professional pilots, they are quite resistant to fatigue. Important for pilots and drivers.

2g. ***Vigilance.*** The human brain does a poor job, normally, of remaining alert in a boring situation, waiting for an important but rare occurrence. Even mild fatigue makes the situation worse. Especially important for security guards, aircrews dependent upon autopilots, personnel monitoring satellite warning systems, etc.

2h. ***Narrowed attention.*** Fatigue causes us to shed tasks, decreasing the number of things that we try to pay attention to. Similar to the tired or distracted pilot's "channelized attention" (an undue focus on one parameter of flight to the exclusion of other essential parameters). Important for both command and control teams and for aircrews.

2i. ***Hypnagogic hallucinations.*** Dreams that occur during wakefulness, especially during the pre-dawn hours. A not-uncommon symptom of moderate to severe cumulative fatigue.

3a. ***Willingness to accept greater risk.*** Limited research suggests that alcohol causes you to be more willing to take a risk even though your ability to estimate risk remains fairly accurate. For example, you may opt to not follow standard procedures or you may perform activities with greater risk than you usually accept. Fatigue appears to have the same effect (not supported by research; under investigation). Important for pilots, command and control teams and drivers.

3b. ***Loss of situation awareness.*** "Continuous extraction of environmental information, integration of this information with previous knowledge to form a coherent mental picture, and the use of that picture in directing further perception and anticipating future events." (C Dominguez, 1995). Depends upon working memory, and is impaired by both retrograde and anterograde amnesia. Especially important for command and control teams and aircrews.

4. ***Mood impairment.*** The emotional state generated by the interaction of the individual with the physical and human environments. For example, impaired mood may be characterized by depression, lack of motivation and/or reluctance to participate or communicate with others. Important for command and control teams and for aircrew resource management (CRM). *Motivation.* "An internal process that pushes or pulls the individual, and the push or pull relates to some external event." Involves drive, desire and goal orientation. (ED Ferguson, 2000)

5a. ***General malaise.*** The overall, undesirable feeling caused by illness and by cumulative fatigue and jet lag. Includes physical, cognitive and emotional components.

5b. ***Aerobic capacity***. Your maximum capacity to perform endurance-requiring physical activities. The normal circadian rhythm in metabolic function reduces aerobic capacity about 10% during the pre-dawn hours, compared to mid-day. Cumulative fatigue may have a similar effect.

5c. ***Drowsiness.*** The state of diminished responsiveness between relaxed wakefulness and sleep. Subtle changes in the environment may not be perceived. For example, a drowsy driver may not perceive a slow drift off the side of the road.

5d. ***Sleep debt, recovery sleep.*** Eventually, missed sleep must be made up. That is, you must repay the sleep debt that you incur. Fortunately, the payback requirement is less than the debt (such a deal!) at a ratio of about 2.5 to 1. For example, if you need 8 hours of sleep at night and get only 5, you carry a sleep debt of 3 hours forward to the next night. In the absence of an environmental or circadian disturbance or a requirement to get out of bed, you will probably sleep for your regular 8 hours plus another (3 / 2.5 =) 1.2 hours.

5e. ***Falling asleep on the job.*** The state of diminished responsiveness beyond drowsiness, especially frank episodes of sleep lasting from a few seconds to several minutes. Obvious changes in the environment and the occurrence of the sleep episode may not be perceived by the individual.

5f. ***Dizziness.*** The subjective condition of faintness, vertigo, gait disturbance, or abnormal head sensation; the latter two symptoms are the more likely to occur as a result of fatigue. Important for aircrews.

5g. ***Decreased altitude tolerance.*** Cumulative fatigue may reduce the responsiveness of the physiological acclimatization mechanisms needed to operate at moderate and high altitudes. Not supported by research; under investigation.

5h. ***Decreased thermal tolerance.*** Cumulative fatigue may reduce the responsiveness of the physiological acclimatization mechanisms needed to operate in high ambient temperatures. Not supported by research; under investigation.

5i. ***Decreased acceleration tolerance.*** Cumulative fatigue may reduce the strength and endurance needed by a fighter/attack crew to sustain high acceleration (not supported by research; under investigation).

5j. ***Cardiovascular health effects.*** Especially, chronically elevated blood pressure. Known to occur in long-term shiftworkers.

5k. ***Gastrointestinal health effects.*** Especially, indigestion and ulcers. Known to occur in night- and shiftworkers.

6a. ***Worsening of alcohol effects.*** Both alcohol and cumulative fatigue appear to have similar and somewhat additive effects on response time (slower and more variable), response accuracy (less accurate and more variable), and manual control (slower and more variable).

Both may also encourage the acceptance of greater levels of risk. Alcohol can add to drowsiness and cause more rapid than normal sleep onset. However, it then impairs subsequent sleep, reducing potential recovery.

6b. *Modulation of drug effects.* There is an interdependence between human circadian rhythms and the risk factors, pharmacologic sensitivity, and pharmacokinetics of many drugs.

7a. *Reduced interpersonal communications.* Fatigue causes us to shed tasks, decreasing the number of things that we try to pay attention to. One of the first things to go is communications. Important for command and control teams and for aircrew resource management (CRM).

7b. *Loss of shared situation awareness.* "Continuous extraction of environmental information, integration of this information with previous knowledge to form a coherent mental picture, and the use of that picture in directing further perception and anticipating future events." (C Dominguez, 1995). Depends upon working memory, and is impaired by both retrograde and anterograde amnesia. In crew or team situations, failures to share critical flight information or to point out mistakes may lead to reduced shared situation awareness. Especially important for command and control teams and aircrews.

Added Drug Hazards

Hangover. Undesirable drug effects that linger well after the period of desired effect. For example, some older sleep aids caused anterograde amnesia that extended well beyond the period of sleep that they helped provide. The best-known hangover effect is that of alcohol. Even after alcohol has been eliminated from the body, there may be undesired effects on cognitive performance and mood, some of which may be related to sleep disruption and others to the remaining presence of the breakdown products of alcohol.

Rebound insomnia. An insomnia that may occur when one stops the use of a sleep aid.

Withdrawal. Undesirable drug effects that linger well after repeated use has stopped. For example, rebound insomnia is usually one characteristic of withdrawal from the repeated use of some sleep aids.